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“Item Perspectiva ist ein lateinisch Wort, bedeußt ein Durchsehung” (“*Perspectiva* is a Latin word which means ‘seeing through.’”). This is how Dürer sought to explain the concept of perspective.¹ And although this *lateinisch Wort* was used already by Boethius,² and did not originally bear so precise a meaning,³ we shall nevertheless adopt in essence Dürer’s definition. We shall speak of a fully “perspectival” view of space not when mere isolated objects, such as houses or furniture, are represented in “foreshortening,” but rather only when the entire picture has been transformed – to cite another Renaissance theoretician – into a “window,” and when we are meant to believe we are looking through this window into a space.⁴ The material surface upon which the individual figures or objects are drawn or painted or carved is thus negated, and instead reinterpreted as a mere “picture plane.” Upon this picture plane is projected the spatial continuum which is seen through it and which is understood to contain all the various individual objects.⁵

So far it does not matter whether this projection is determined by an immediate sensory impression or by a more or less “correct” geometrical construction. This correct construction was in fact invented in the Renaissance, and although later subjected to

various technical improvements and simplifications, it nevertheless remained in its premises and goals unchanged to the time of Desargues. It is most simply explained as follows: I imagine the picture – in accord with the “window” definition – as a planar cross section through the so-called visual pyramid; the apex of this pyramid is the eye, which is then connected with individual points within the space to be represented. Because the relative position of these “visual rays” determines the apparent position of the corresponding points in the visual image, I need only draw the entire system in plan and elevation in order to determine the figure appearing on the intersecting surface. The plan yields the width, the elevation yields the height; and if I combine these values on a third drawing, I will obtain the desired perspectival projection (Figure 1).

In a picture constructed this way – that is, by means of what Dürer called a “planar, transparent intersection of all those rays that fall from the eye onto the object it sees”⁶ – the following laws are valid. First, all perpendiculars or “orthogonals” meet at the so-called central vanishing point, which is determined by the perpendicular drawn from the eye to the picture plane. Second, all parallels, in whatever direction they lie, have a common vanishing point. If they lie in a horizontal plane, then their vanishing point lies always on the so-called horizon, that is, on the horizontal line through the central vanishing point. If, moreover, they happen to form a 45-degree angle with the picture plane, then the distance between their vanishing point and the central vanishing point is equal to the distance between the eye and the picture plane. Finally, equal dimensions diminish progressively as they recede in space, so that any portion of the picture – assuming that the location of the eye is known – is calculable from the preceding or following portion (see Figure 7).

In order to guarantee a fully rational – that is, infinite, un-

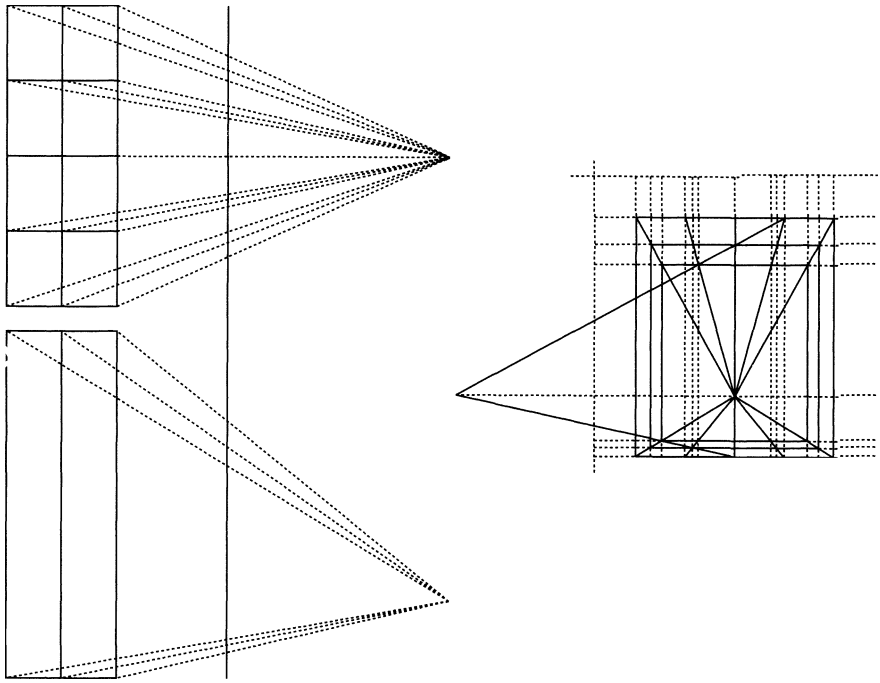


FIGURE 1. Modern “linear perspective” construction of a rectangular interior space (“space box”). Left above: plan. Left below: elevation. Right: perspectival image arrived at by combining the segments marked off on the “projection line.”

changing and homogeneous – space, this “central perspective” makes two tacit but essential assumptions: first, that we see with a single and immobile eye, and second, that the planar cross section of the visual pyramid can pass for an adequate reproduction of our optical image. In fact these two premises are rather bold abstractions from reality, if by “reality” we mean the actual subjective optical impression. For the structure of an infinite, unchanging and homogeneous space – in short, a purely mathematical

space – is quite unlike the structure of psychophysiological space: “Perception does not know the concept of infinity; from the very outset it is confined within certain spatial limits imposed by our faculty of perception. And in connection with perceptual space we can no more speak of homogeneity than of infinity. The ultimate basis of the homogeneity of geometric space is that all its elements, the ‘points’ which are joined in it, are mere determinations of position, possessing no independent content of their own outside of this relation, this position which they occupy in relation to each other. Their reality is exhausted in their reciprocal relation: it is a purely functional and not a substantial reality. Because fundamentally these points are devoid of all content, because they have become mere expressions of ideal relations, they can raise no question of a diversity in content. Their homogeneity signifies nothing other than this similarity of structure, grounded in their common logical function, their common ideal purpose and meaning. Hence homogeneous space is never given space, but space produced by construction; and indeed the geometrical concept of homogeneity can be expressed by the postulate that from every point in space it must be possible to draw similar figures in all directions and magnitudes. Nowhere in the space of immediate perception can this postulate be fulfilled. Here there is no strict homogeneity of position and direction; each place has its own mode and its own value. Visual space and tactical space [*Tastraum*] are both anisotropic and unhomogeneous in contrast to the metric space of Euclidean geometry: ‘the main directions of organization – before–behind, above–below, right–left – are dissimilar in both physiological spaces.’ ”⁷

Exact perspectival construction is a systematic abstraction from the structure of this psychophysiological space. For it is not only the effect of perspectival construction, but indeed its intended purpose, to realize in the representation of space pre-

cisely that homogeneity and boundlessness foreign to the direct experience of that space. In a sense, perspective transforms psychophysiological space into mathematical space. It negates the differences between front and back, between right and left, between bodies and intervening space ("empty" space), so that the sum of all the parts of space and all its contents are absorbed into a single "quantum continuum." It forgets that we see not with a single fixed eye but with two constantly moving eyes, resulting in a spheroidal field of vision. It takes no account of the enormous difference between the psychologically conditioned "visual image" through which the visible world is brought to our consciousness, and the mechanically conditioned "retinal image" which paints itself upon our physical eye. For a peculiar stabilizing tendency within our consciousness – promoted by the cooperation of vision with the tactile sense – ascribes to perceived objects a definite and proper size and form, and thus tends not to take notice, at least not full notice, of the distortions which these sizes and forms suffer on the retina. Finally, perspectival construction ignores the crucial circumstance that this retinal image – entirely apart from its subsequent psychological "interpretation," and even apart from the fact that the eyes move – is a projection not on a flat but on a concave surface. Thus already on this lowest, still prepsychological level of facts there is a fundamental discrepancy between "reality" and its construction. This is also true, of course, for the entirely analogous operation of the camera.

If, to choose a very simple example, a line is divided so that its three sections *a*, *b* and *c* subtend equal angles, these objectively unequal sections will be represented on a concave surface (like the retina) as approximately equal lengths; whereas if projected on a flat surface they will appear, as before, as unequal lengths (Figure 2). This is the source of those marginal distortions

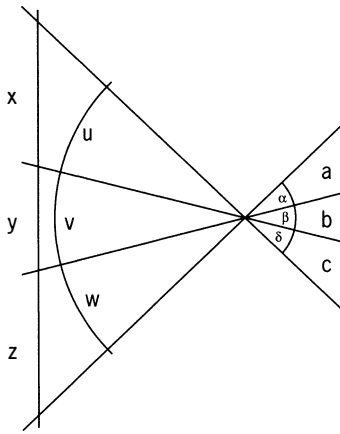


FIGURE 2. Explanation of the “marginal distortions.”

which are most familiar to us from photography, but which also distinguish the perspectively constructed image from the retinal image. These distortions can be mathematically expressed as the discrepancy between, on the one hand, the ratio of the visual angles and, on the other hand, the ratio of the linear sections produced by projection upon a flat surface. The wider the total or composite visual angle – that is, the smaller the ratio between the distance from eye to image and the size of the image – the more pronounced the distortion.⁸ But alongside this purely quantitative discrepancy between retinal image and perspectival representation, which was recognized already in the early Renaissance, there is as well a formal discrepancy. This latter follows, in the first place, from the movement of the gaze, and in the second place, once again, from the curvature of the retina: for while perspective projects straight lines as straight lines, our eye perceives them (from the center of projection) as convex curves. A normal checkerboard pattern appears at close range to swell out in the

form of a shield; an objectively curved checkerboard, by the same token, will straighten itself out. The orthogonals of a building, which in normal perspectival construction appear straight, would, if they were to correspond to the factual retinal image, have to be drawn as curves. Strictly speaking, even the verticals would have to submit to some bending (*pace* Guido Hauck, whose drawing is reproduced as Figure 3).

This curvature of the optical image has been observed twice in modern times: by the great psychologists and physicists at the end of the last century;⁹ but also (and this has apparently not been remarked upon until now) by the great astronomers and mathematicians at the beginning of the seventeenth century. We should recall above all the words of the remarkable Wilhelm Schickhardt, a cousin of the Württemberg architect and Italian traveler, Heinrich Schickhardt: "I say that all lines, even the straightest, which do not stand *directe contra pupillam* [directly in front of the eye]... necessarily appear somewhat bent. Never-

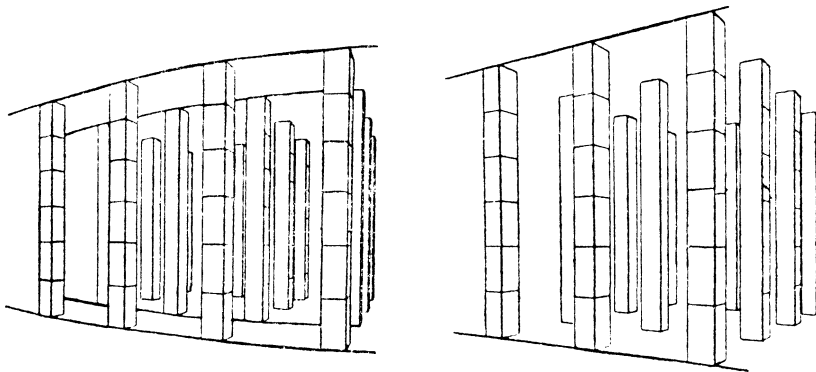


FIGURE 3. Hall of pillars constructed according to "subjective" or curved perspective (left) and according to schematic or linear perspective (right). (After Guido Hauck.)

theless, no painter believes this; this is why they paint the straight sides of a building with straight lines, even though according to the true art of perspective this is incorrect. . . . Crack that nut, you artists!”¹⁰ This was endorsed by none other than Kepler, at least insofar as he admitted the possibility that the objectively straight tail of a comet or the objectively straight trajectory of a meteor is subjectively perceived as a curve. What is most interesting is that Kepler fully recognized that he had originally overlooked or even denied these illusory curves only because he had been schooled in linear perspective. He had been led by the rules of painterly perspective to believe that straight is always seen as straight, without stopping to consider that the eye in fact projects not onto a *plana tabella* but onto the inner surface of a sphere.¹¹ And indeed, if even today only a very few of us have perceived these curvatures, that too is surely in part due to our habituation – further reinforced by looking at photographs – to linear perspectival construction: a construction that is itself comprehensible only for a quite specific, indeed specifically modern, sense of space, or if you will, sense of the world.

Thus in an epoch whose perception was governed by a conception of space expressed by strict linear perspective, the curvatures of our, so to speak, spheroidal optical world had to be rediscovered. However, in a time that was accustomed to seeing perspectivally – but not in linear perspective – these curvatures were simply taken for granted: that is, in antiquity. In antique optics and art theory (as well as in philosophy, although here only in the form of analogies) we constantly encounter the observations that straight lines are seen as curved and curved lines as straight; that columns must be subjected to *entasis* (usually relatively weak, of course, in classical times) in order not to appear bent; that epistyle and stylobate must be built curved in order to avoid the impression of sagging. And, indeed, the familiar

curvatures of the Doric temple attest to the practical consequences of such findings.¹² Antique optics, which brought all these insights to fruition, was thus in its first principles quite antithetical to linear perspective. And if it did understand so clearly the spherical distortions of form, this only follows from (or at least corresponds to) its still more momentous recognition of the distortions of magnitude. For here, too, antique optics fit its theory more snugly to the factual structure of the subjective optical impression than did Renaissance perspective. Because it conceived of the field of vision as a sphere,¹³ antique optics maintained, always and without exception, that apparent magnitudes (that is, projections of objects onto that spherical field of vision) are determined not by the distances of the objects from the eye, but rather exclusively by the width of the angles of vision. Thus the relationship between the magnitudes of objects is, strictly speaking, expressible only in degrees of angle or arc, and not in simple measures of length.¹⁴ Indeed Euclid's Eighth Theorem explicitly preempts any opposing view. Euclid states that the apparent difference between two equal magnitudes perceived from unequal distances is determined not by the ratio of these distances, but rather by the far less discrepant ratio of the angles of vision (Figure 4).¹⁵ This is diametrically opposed to the doctrine behind modern perspectival construction, familiar in the formula of Jean Pélerin, known as Viator: "*Les quantitez et les distances Ont concordables différences*" ("The quantities and the distances vary proportionally").¹⁶ And perhaps it is more than mere accident that in Renaissance paraphrases of Euclid, indeed even in translations, precisely this Eighth Theorem was either entirely suppressed or "emended" until it lost its original meaning.¹⁷ Evidently, the contradiction was felt between Euclid's *perspectiva naturalis* or *communis*, which sought simply to formulate mathematically the laws of natural vision (and so linked apparent size to the visual angle),

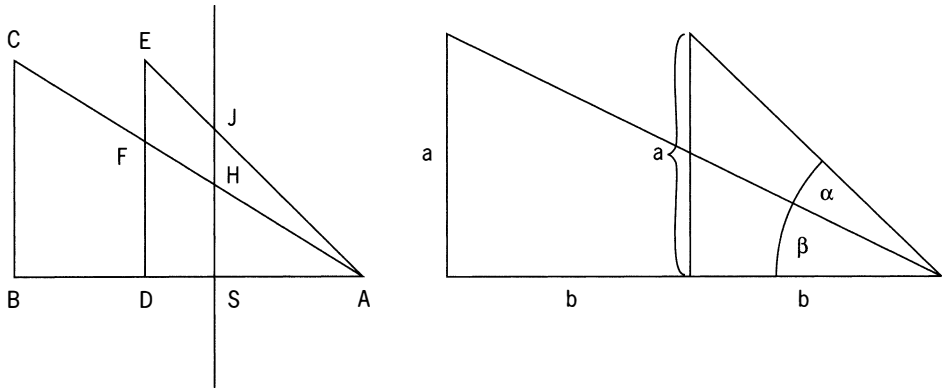


FIGURE 4. Contrast between the “linear perspectival” and “angle-perspectival” constructions: in linear perspective (left), the apparent sizes (HS and JS) are inversely proportional to the distances (AB and AD); in angle perspective (right), the apparent sizes (β and $\alpha + \beta$) are not inversely proportional to the distances ($2b$ and b).

and the *perspectiva artificialis* developed in the meantime, which on the contrary tried to provide a serviceable method for constructing images on two-dimensional surfaces. Clearly, this contradiction could be resolved only by abandoning the angle axiom; to recognize the axiom is to expose the creation of a perspectival image as, strictly speaking, an impossible task, for a sphere obviously cannot be unrolled on a surface.